Supplementary Material

Critical Issues in the Development of Health Information Systems in Supporting Environmental Health: A Case Study of Ciguatera

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Phase 1: Hazard identification and regional hazard mapping of ciguatera in the pacific

Integrate and/or link relevant literature with spatial environmental and health databases - to identify and rank regions by risk of ciguatera exposure. The principal health-related output is to create regional hazard profiles across the PICT region where ciguatera has impacted, or is likely to impact on human health.

Advances in technology have made the exchange of data easier than before, with the use of integrated databases becoming central to the effective maintenance, communication and utilisation of public health data for policy development and interventions. However, it needs to be established the extent to which existing datasets can be readily used to capture and forecast changing environmental health issues arising from climate change.

Integrating the ICFMaP ciguatera case information for the Pacific with fish species records in FishBase (FishBase 2004), although an excellent initiative, nevertheless lacked the scope to retrieve information for the development of proactive public health interventions. Modification of the database so that all ciguatera cases could be retrieved and plotted spatially, *sensu* the approach of Stinn et al (1998) in Florida, would enable more effective analysis of disparate epidemiological and environmental datasets. For example, the capacity to link ciguatera case-history data with fish species data would facilitate preparation of spatial hazard maps for ‘upstream’ sources of ciguatera risk. Similarly, linking FishBase data with coral reef and algal habitat monitoring networks, such as ReefGIS (Tupper et al. 2009) and AlgaeBase (Guiry et al. 2010) would help identify additional environmental criteria needed to trigger public health action and prioritise areas for focused site investigations into the aetiology of ecological and anthropogenic influences on ciguatoxin prevalence (see Phase 2).

A stock-take of relevant national and regional scale data and information systems should be undertaken across a range of interdisciplinary data sources. Relevant data topics would include: human health (ciguatera case-histories and outbreaks), climate change (sea surface temperature increases), marine environment (recreational and commercial use, current systems), land (cover and use), ecosystems and biodiversity (coral reefs, including flora and fauna) and natural hazards (cyclones, tsunamis, flood events). Most of these datasets are freely available on the internet, although quality and relevance should remain key considerations when sourcing data to inform HIS. Importantly, the probabilistic nature and limitations of each dataset should be accounted for during the stock-take to determine how the data must be treated when compared. Further, when assessing the risks of climate change impacts on ciguatera the magnitude of uncertainty is going to be high. Thus, hazard profile categories (based on likelihood and probability of exposure to ciguatoxic fish and accounting for uncertainty) could be generated from either expert opinion and/or data driven sources, with multiple hazard categories developed to trigger public health action and prioritise further field investigations.

Bayesian models, in particular Bayesian networks (BN), are an example of a tool that permits the integration of data-driven or expert knowledge information sources, while accounting for all known assumptions and uncertainties in a single theoretical environment (Pike 2004). Primarily developed in the field of ecology and environmental management (Varis 1995), BNs have been applied increasingly to other disciplines including public health (McDonald et al. 2009), as they are flexible and pragmatic, allowing for risks to be quantified where multiple hazards exist (Cain 2001). A further advantage of this statistical tool is that it can be updated with new information as it becomes available, an essential requirement of risk assessment and prevention. Most importantly, BNs provide a mechanism by which to use existing datasets to prioritise and target additional data collection where it is needed, reducing uncertainty and strengthening ciguatera risk profiles (McDonald et al 2009).

Phase 2: Establish 'reef health' indicators as a function of ciguatera risk

Using the prioritised outputs from (1) undertake focused field investigations on biotic and abiotic factors triggering the onset of ciguatoxins and subsequent outbreaks among consumers. The principal health-related output would be a series of progressively aggressive 'reef health' indicators of likelihood and consequence of exposure to ciguatera and subsequent public health actions.

While recommendations (by the SPC and IRD) to collect algae and fish species data during follow up field surveys was an excellent initiative, the lack of an ecological context for interpreting this information was an oversight. To rectify this we propose that a 'whole of ecosystem' approach to ciguatera research be adopted, with the specific intention of developing criteria for proactive public health action. By focusing applied research across a number of case study sites, a working knowledge base could be established on why ciguatera outbreaks occur, the factors (natural or anthropogenic) that destabilise reef systems, the ratios of toxic fish to dinoflagellate populations (including seasonality), and the link between these changes and human cases of ciguatera. Using these datasets it will be possible to establish a series of "reef health" indicators based on single or multiple environmental criteria of likely ciguatera exposure, as well as progressive monitoring and public health actions commensurate with established environmental triggers.

Small-scale water quality monitoring devices, such as *in-situ* loggers, could be deployed as an early warning system of suitable conditions for ciguatoxin production and so trigger the collection of 'reef health' indicator data. Regular collection of dinoflagellate abundance data from the macro algae hosts will also trigger the need for further investigations if highly toxic genetic strains are detected within the population. As filter feeders, invertebrates are likely to show signs of recent or renewed contamination within the fish food chain; monitoring these species could act as a trigger for preliminary public health action such as raising awareness in the community at risk of possible future fish restrictions. Vertebrate species are higher order consumers so detection of toxins in these species should lead to immediate notification of species not to be consumed and the placement of controls on fish stocks from affected areas. A relevant and practical information product might include a monthly bulletin and/or bi-annual poster of relative risk of ciguatera, by region, for preferred eating species based on cumulative "reef health" indicator information that can be posted on any marina notice board. The longer term objective would be that all monitoring data are regularly fed back into existing broader-scale spatial datasets. The unanswerable question at this stage is which organisation would have responsibility.

Phase 3: Future risk projections of ciguatera in the pacific for public health action

Interpret the outputs from (1) and (2) in the context of climate change projections for the Pacific. The principle heath-related outcome is to inform an adaptive governance strategy and framework to support policy making, regulation along-side coral reef and fish stock management.

The compilation of broader-scale and intensive short-term projects undertaken across a variety of environmental conditions will provide a basis for modelling long-term effects of ciguatera in the Pacific resulting from climate change. The use of spatial analysis tools such as Geographical Information Systems (GIS) for risk modelling is now well established (Lawson, 2004; WHO 2010) and provides an opportunity to improve the capacity of HIS to make timely population-scale health decisions. GIS linked data collection and storage facilitates timely health interventions by enabling the more easily interpreted visual communication of information to a wide range of audiences. This approach enables the efficient and consistent updating of information, provides a spatial context at multiple scales and facilitates integration with other supporting systems and models (Girgin et al., 2005). The modelling and statistical capabilities of GIS are suited for analysing environmental (e.g. climate change (BOM, 2010), global hazard (Munchener Ruck, 2009), coral reef (Tupper et al., 2009), fish species (FishBase, 2004) data alongside detailed records of ciguatera to improve existing and future health practice in the Pacific. One potential health related output would be an integrated spatial tool with which to identify and rank PICT regions with respect to likelihood of experiencing ciguatera food poisoning in the context of climate and/or environmental change. Such a tool would provide a platform from which to: 1) establish an adaptive governance strategy for health policy making by closing the HIS feedback loop and 2) identify good HIS practice and use these as flagships for other at risk communities. An adoption of this approach would see the establishment of a monitoring network linking multiple environmental data sources with ciguatera case data using GIS technology as an interactive reporting output for research and public health interventions.

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